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(54) **COMBUSTOR AND GAS TURBINE**

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F23R 3/08 (2006.01)

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(52) **U.S. Cl.**

CPC ***F23R 3/08*** (2013.01); ***F02C 3/30*** (2013.01); ***F02C 7/22*** (2013.01); ***F23L 7/002*** (2013.01);

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(57) **ABSTRACT**

A combustor includes an outer cylinder, a combustor liner, a plurality of main nozzles, an air flow channel part, and a plurality of water injection parts. The air flow channel part sends air introduced from an outside to between an inner peripheral surface of the outer cylinder and an outer peripheral surface of the combustor liner into the combustor liner. The plurality of water injection parts are provided on the inner peripheral surface of the outer cylinder at intervals in a circumferential direction around a central axis. The plurality of water injection parts inject water into the air flowing through the air flow channel part. The water injection part

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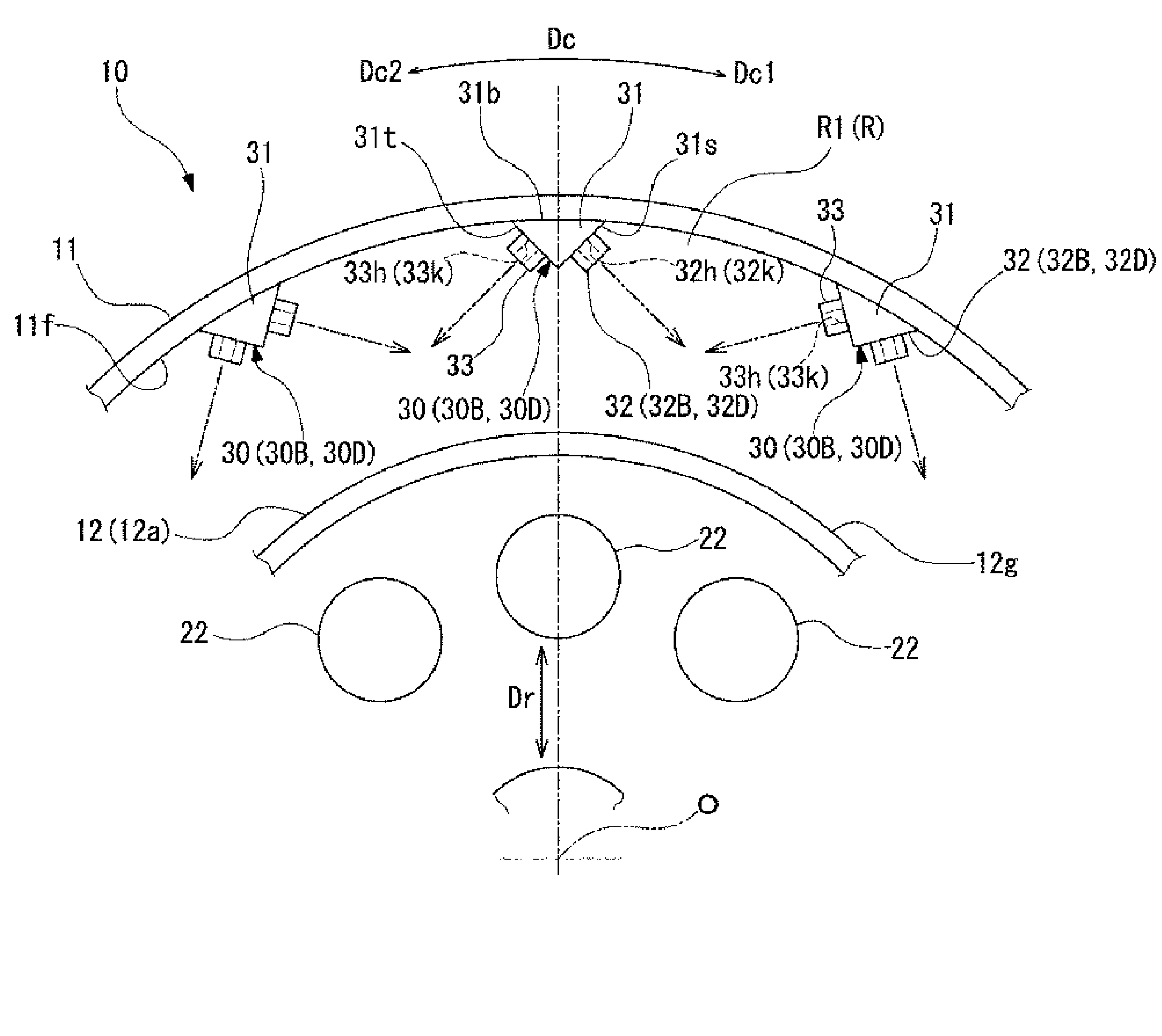

includes a first nozzle and a second nozzle. The first nozzle injects water to a first side in the circumferential direction. The second nozzle injects water to a second side in the circumferential direction.

8 Claims, 9 Drawing Sheets

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F23L 7/00 (2006.01)
F23C 9/08 (2006.01)

(52) **U.S. Cl.**
CPC *F05D 2220/32* (2013.01); *F05D 2240/35* (2013.01); *F23C 9/08* (2013.01); *F23L 2900/07008* (2013.01)

(58) **Field of Classification Search**
USPC 60/775, 39.53
See application file for complete search history.

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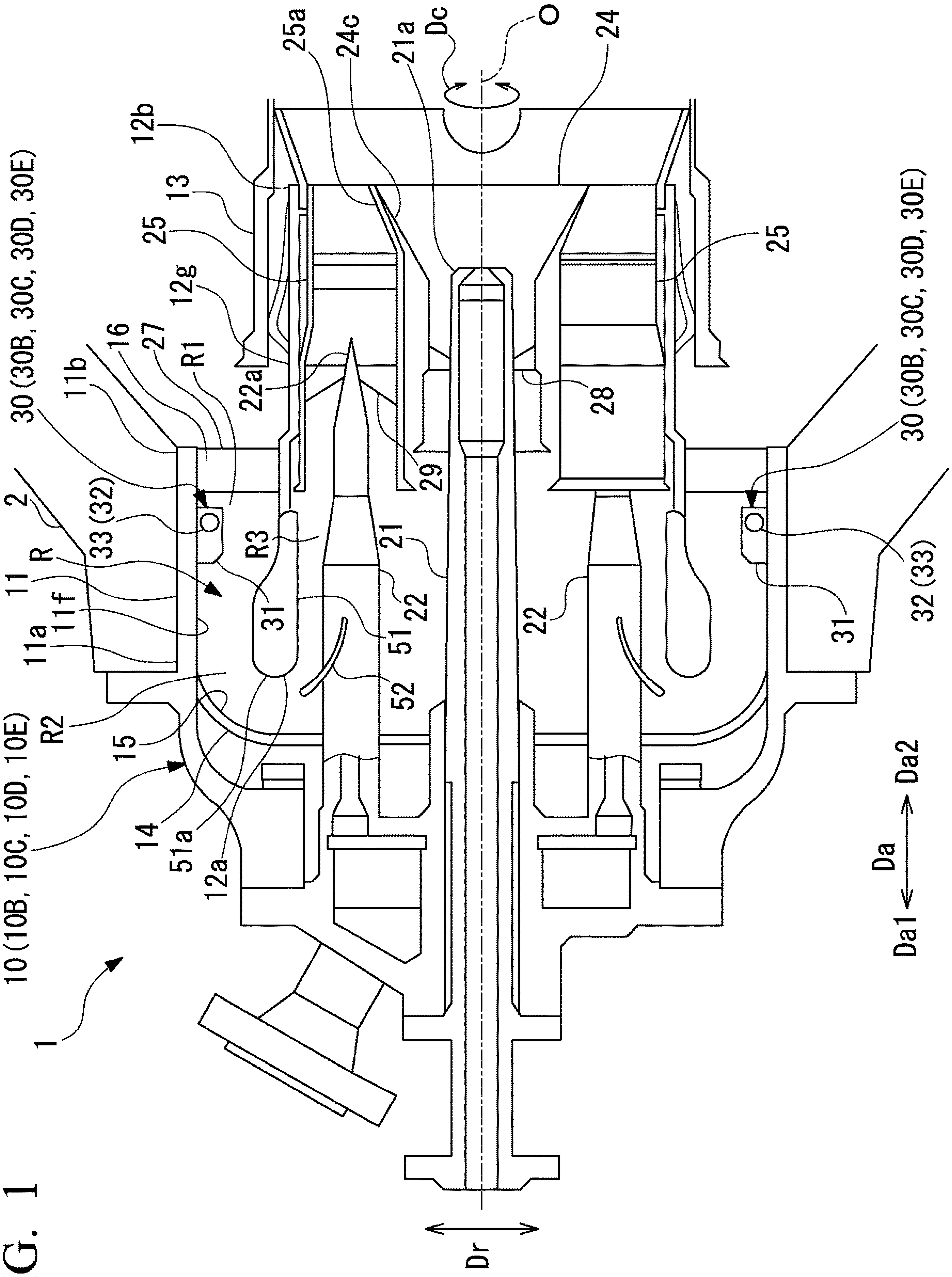
FIG. 1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10 (10B, 10C, 10D, 10E)
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11
11a
11b
11f
12a
12b
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14
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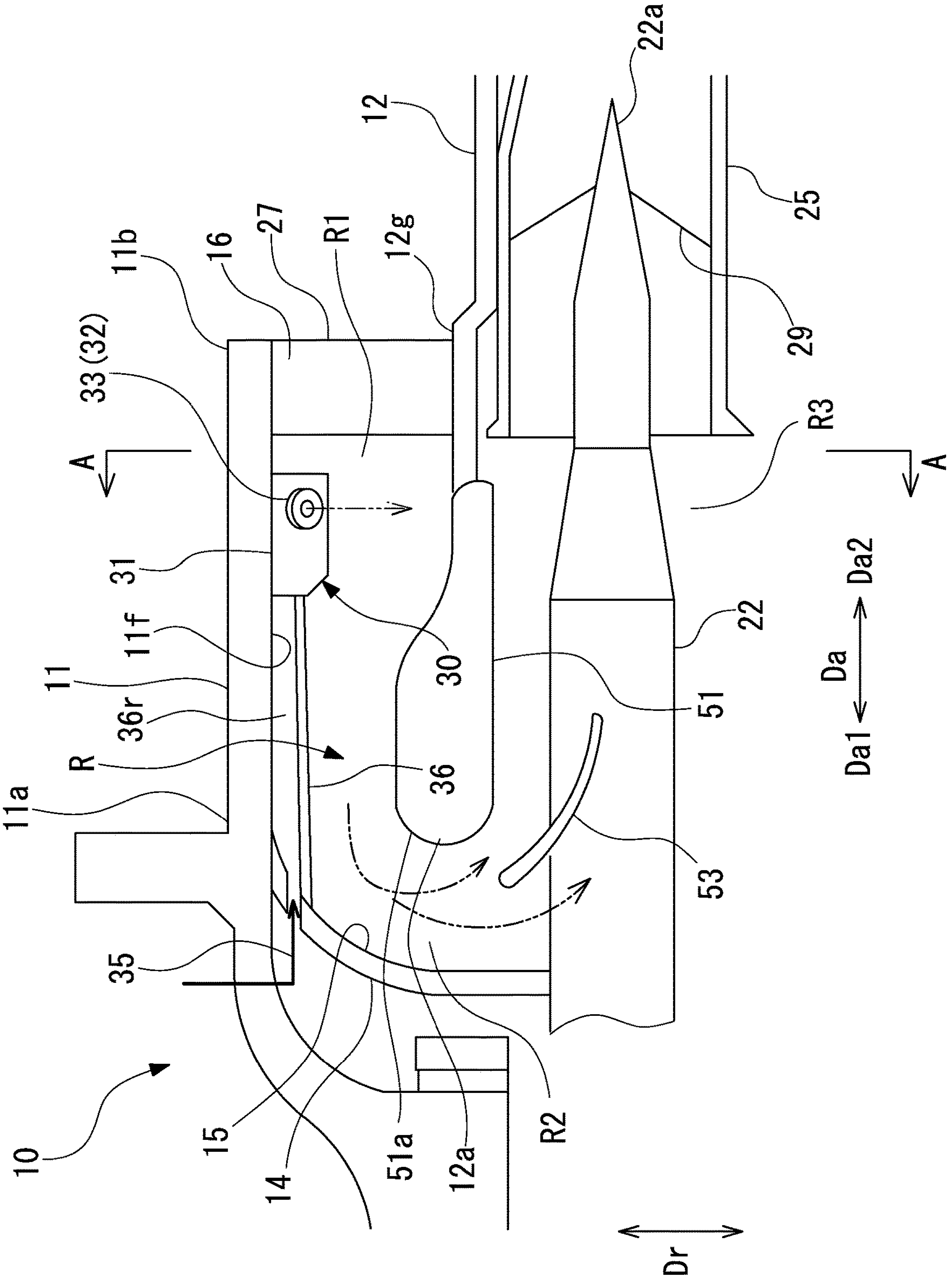
21a
22
22a
24
24c
25
25a
27
28
29
30 (30B, 30C, 30D, 30E)
31
32 (33)
33 (32)
51
51a
52
R
R1
R2
R3
O
Dc
Dr
Da
Da1
Da2

FIG. 2



22a
12
25
11b
16
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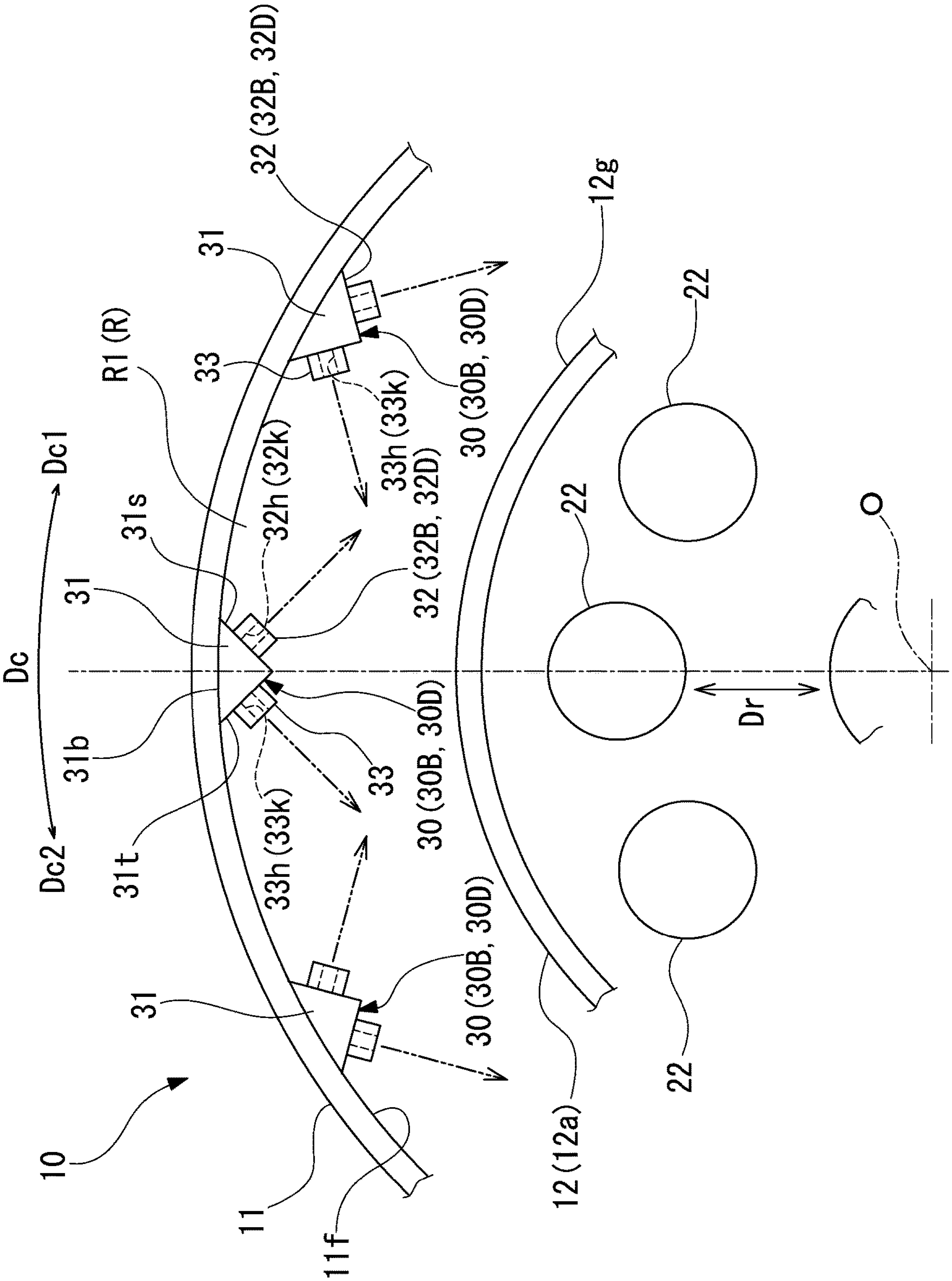
R1
12g
29
33 (32)
A
R3
A
31
Da2
22
11f
30
51
11
Da
36r
R
36
Da1
11a
53
35
15
51a
12a
R2
10
14
Dr

FIG. 3



10
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12 (12a)
12g
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30 (30B, 30D)
30 (30B, 30D)
30 (30B, 30D)
30 (30B, 30D)
31
31
31
31s
31b
31t
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32 (32B, 32D)
32h (32k)
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33h (33k)
33h (33k)
R1 (R)
Dc
Dc1
Dc2
Dr
O

FIG. 4

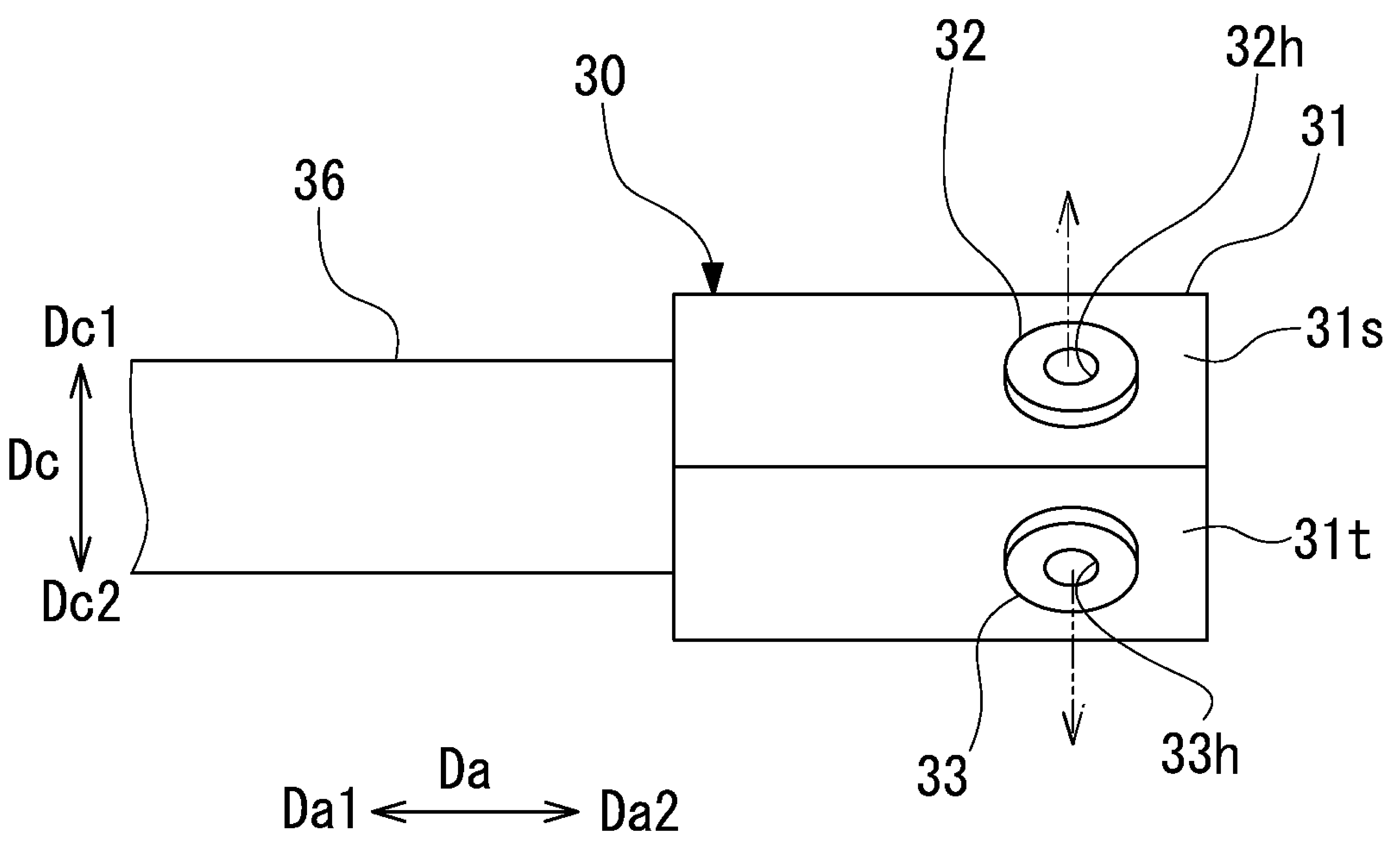
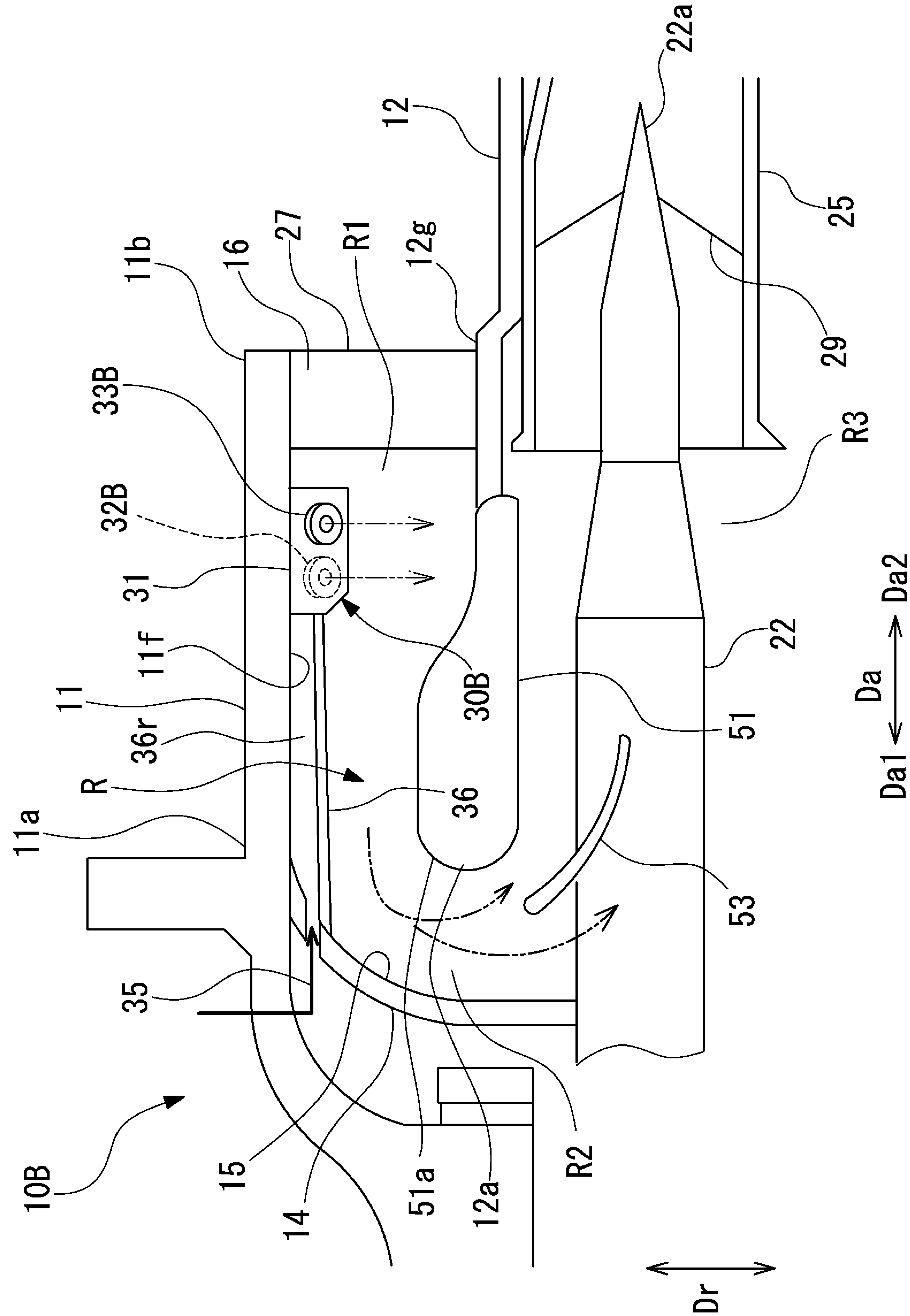


FIG. 5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R2
R3
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Da1
Da2
Dr

FIG. 6

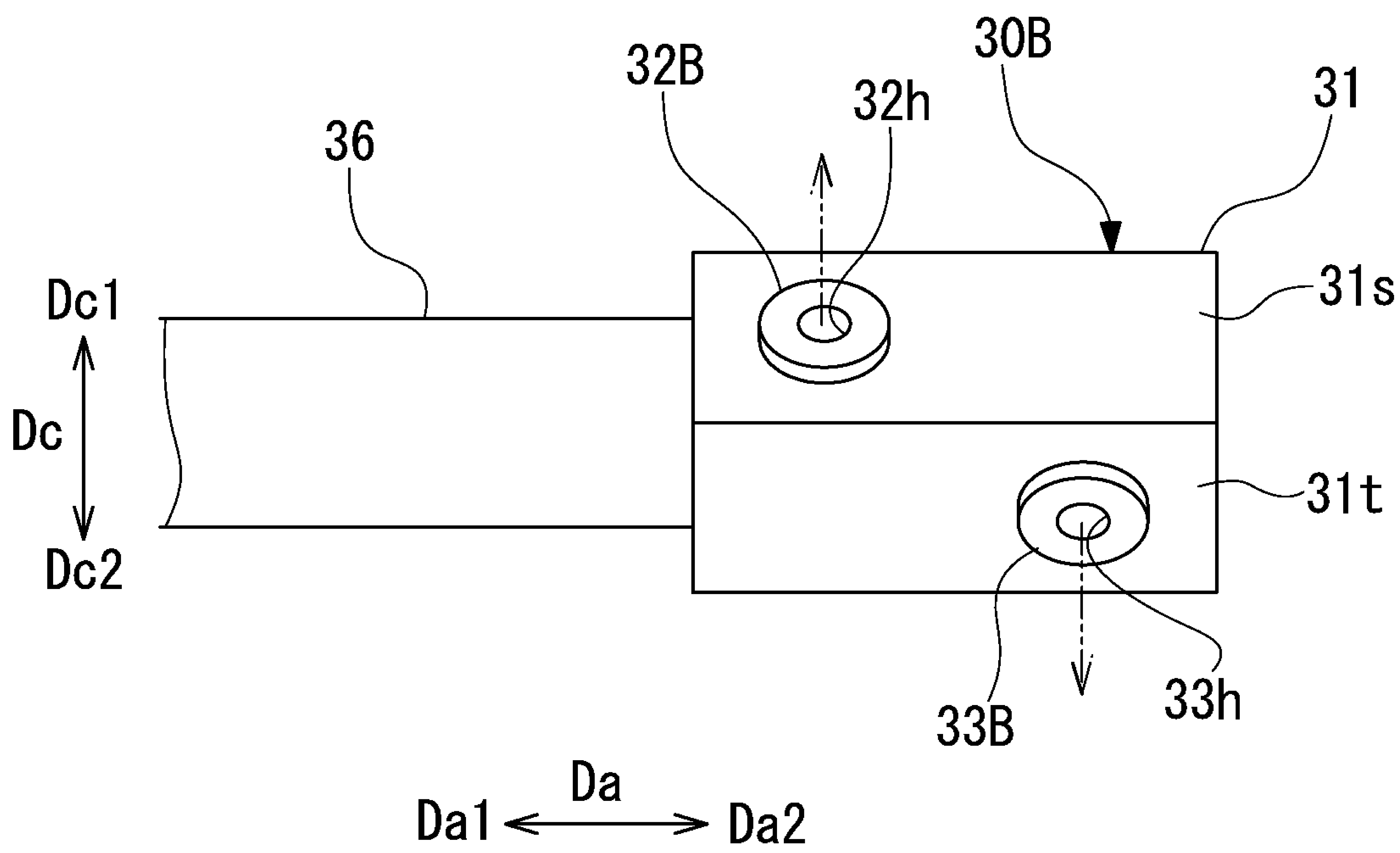
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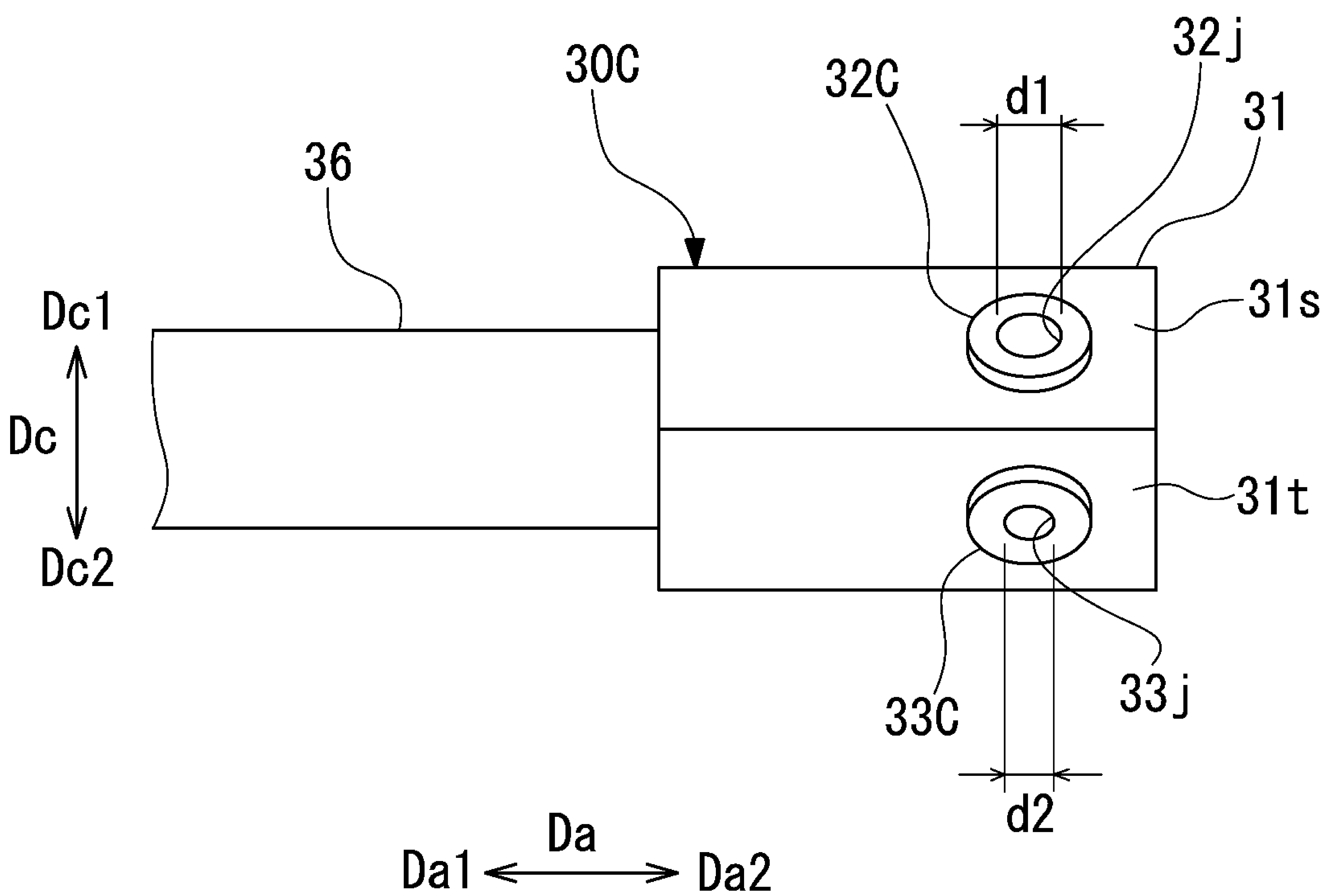
FIG. 7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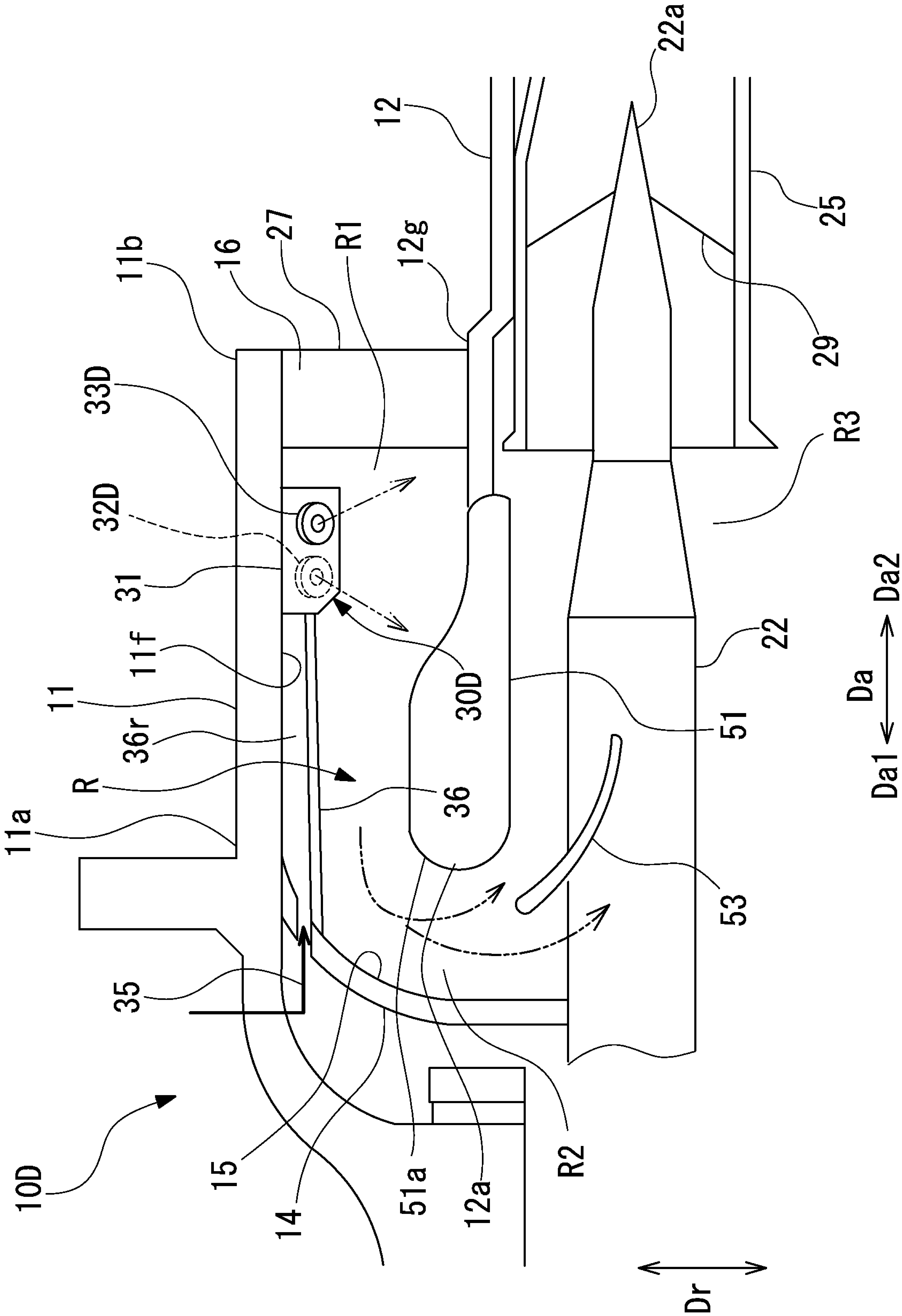
Da2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33D
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R
R1
R2
R3
Da
Da1
Da2
Dr

FIG. 8

FIG. 9

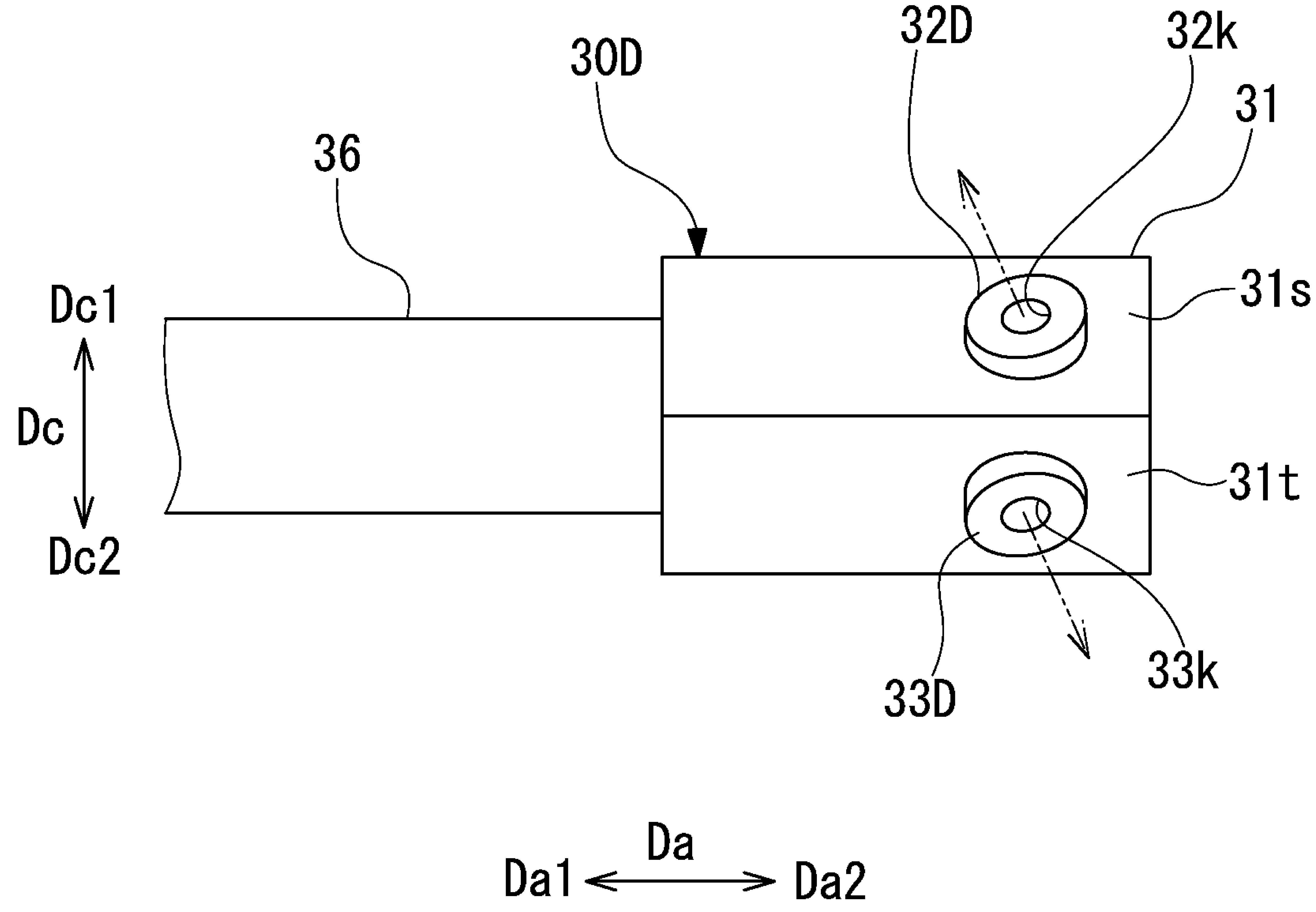
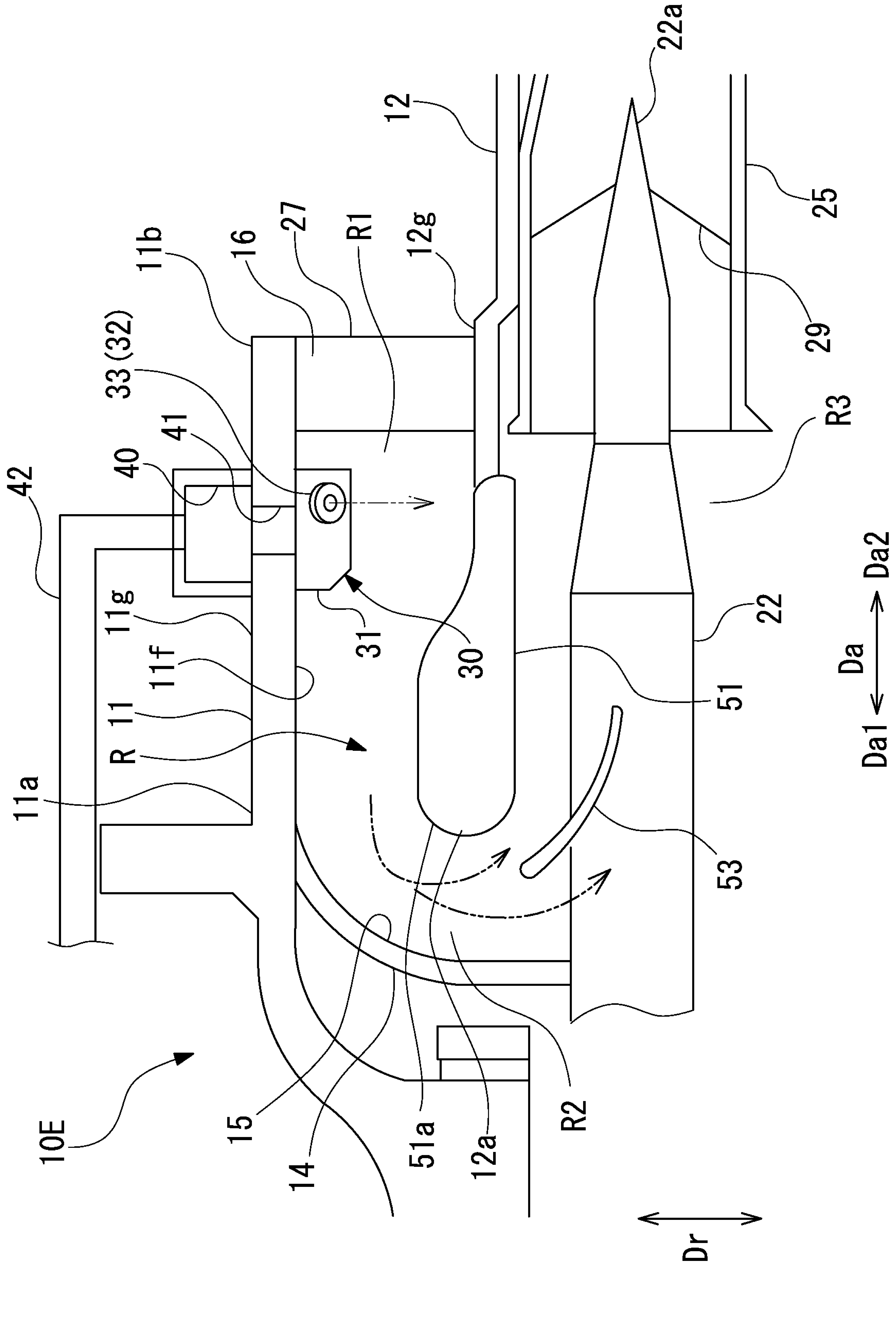


FIG. 10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R3
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Da1
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51
30
31
11g
11f
11
R
11a
53
R2
12a
51a
14
15
10E
Dr

COMBUSTOR AND GAS TURBINE

TECHNICAL FIELD

The present invention relates to combustor and gas turbines.

Priority is claimed on Japanese Patent Application No. 2019-072829, filed Apr. 5, 2019, the content of which is incorporated herein by reference.

BACKGROUND ART

As combustor used in gas turbines, dual-burning combustor capable of burning gas fuel and oil fuel are known. There is known a technique of injecting water together with the oil fuel into a combustion cylinder in a case where oil fuel is burned by such dual-burning combustor.

For example, Patent Document 1 discloses a combustor including a water supply part in an air flow channel formed between an inner peripheral surface of an outer cylinder and an outer peripheral surface of a combustor liner. The air flow channel formed in the combustor of Patent Document 1 includes a reversing part in which the flow direction is reversed at a rear end of the combustor liner. The air that has passed through the reversing part is supplied to a fuel nozzle that injects fuel into the combustor liner. The water supply part is provided before the reversing part of the air flow channel to supply water or steam to the air flowing through the air flow channel. In the combustor of Patent Document 1, water or steam is supplied to the air with the water supply part to reduce the flame temperature of the combustor and NOx (nitrogen oxide), soot, and the like.

CITATION LIST

Patent Document

Patent Document 1: Japanese Unexamined Patent Application, First Publication No. 2014-145563

SUMMARY OF INVENTION

Technical Problem

In the combustor disclosed in Patent Document 1, water is supplied to the air in the air flow channel between the outer cylinder and the combustor liner. For that reason, the water supplied from the water supply part into the air flow channel tends to adhere to an inner peripheral surface on a radially outer side of the reversing part due to a centrifugal force acting on the water at the reversing part. When water adheres to the inner peripheral surface of the reversing part, it is difficult for the water to reach the flame. As a result, there is room for improvement in the effects of reducing the flame temperature in the combustor and reducing NOx and soot.

The present invention has been made in view of the above circumstances, and an object of the present invention is to provide a combustor and a gas turbine capable of further reducing NOx, soot, and the like.

Solution to Problem

The present invention adopts the following means in order to solve the above problems.

According to the first aspect of the present invention, a combustor includes an outer cylinder, a combustor liner, a

plurality of fuel nozzles, an air flow channel part, and a plurality of water injection parts. The outer cylinder has a tubular shape extending in an axial direction. The combustor liner is provided on a radially inner side of the outer cylinder. The combustor liner has a tubular shape extending in the axial direction. The plurality of fuel nozzles are provided inside the combustor liner. The plurality of fuel nozzles are configured to inject fuel. The air flow channel part sends air introduced from an outside to between an inner peripheral surface of the outer cylinder and an outer peripheral surface of the combustor liner into the combustor liner. The plurality of water injection parts are provided on the inner peripheral surface of the outer cylinder at intervals in a circumferential direction around an axis. The plurality of water injection parts inject water toward the radially inner side of the outer cylinder. The water injection part includes a first nozzle and a second nozzle. The first nozzle injects water to a first side in the circumferential direction. The second nozzle injects water to a second side in the circumferential direction.

By adopting such a configuration, the water injection part injects water from the inner peripheral surface of the outer cylinder. The injected liquid droplets are sent into the combustor liner together with the air. Therefore, the liquid droplets are atomized and easily evaporated before reaching a portion where the fuel is injected from the fuel nozzle. Additionally, since water is injected from the inner peripheral surface of the outer cylinder toward the radially inner side of the outer cylinder, even if a centrifugal force acts, the liquid droplets are less likely to be biased radially outward. Therefore, a decrease in the amount of liquid droplets reaching the portion where the fuel is injected from the fuel nozzle is suppressed. Moreover, the first nozzle injects water to the first side in the circumferential direction. The second nozzle injects water to the second side in the circumferential direction. Accordingly, the distribution of the liquid droplets in the air flow channel part becomes non-uniform, and the dispersibility of the liquid droplets is enhanced. Therefore, it is possible to further reduce NOx and soot.

According to a second aspect of the present invention, the water injection part according to the first aspect may include a bracket fixed to the inner peripheral surface of the outer cylinder. The first nozzle and the second nozzle may be provided on the bracket.

By adopting such a configuration, the water injection part can be easily installed only by attaching the bracket provided with the first nozzle and the second nozzle to the inner peripheral surface of the outer cylinder.

According to a third aspect of the present invention, the bracket according to the second aspect may have a first inclined surface and a second inclined surface. The first inclined surface is inclined to the first side in the circumferential direction and is provided with the first nozzle. The second inclined surface is inclined to the second side in the circumferential direction and is provided with the second nozzle.

By adopting such a configuration, the first nozzle provided on the first inclined surface of the bracket injects water to the first side in the circumferential direction. Additionally, the second nozzle provided on the second inclined surface of the bracket injects water to the second side in the circumferential direction. By using such a bracket, the first nozzle and the second nozzle can be easily installed in a state of being inclined in a predetermined direction.

According to a fourth aspect of the present invention, in the combustor according to any one of the first to third aspects, in the water injection parts adjacent to each other in the circumferential direction, the first nozzle of one water injection part and the second nozzle of the other water injection part may be provided at different positions in the axial direction.

By adopting such a configuration, in the water injection parts adjacent to each other in the circumferential direction, the liquid droplets of the water injected from the first nozzle of one water injection part and the liquid droplets of the water injected from the second nozzle of the other water injection part are prevented from interfering with each other. Accordingly, the liquid droplets are prevented from coalescing and increasing in size. Therefore, the liquid droplets are likely to evaporate.

According to a fifth aspect of the present invention, in the combustor according to any one of the first to fourth aspects, in the water injection parts adjacent to each other in the circumferential direction, diameters of nozzle holes for injecting water may be different from each other between the first nozzle and the second nozzle.

By adopting such a configuration, the momentum (flow velocity) of the injected water (liquid droplets) are different between the first nozzle and the second nozzle. Accordingly, distances at which the liquid droplets injected from the first nozzle and the second nozzle, respectively, reach in injection directions are different from each other. Additionally, the grain size of the liquid droplets is also different between the first nozzle and the second nozzle. Accordingly, the distribution of the liquid droplets in the air flow channel part becomes non-uniform, and the dispersibility of the liquid droplets is enhanced.

According to a sixth aspect of the present invention, in the combustor according to any one of the first to fifth aspects, in the water injection parts adjacent to each other in the circumferential direction, the first nozzle and the second nozzle may have water injection directions that are different from each other in the axial direction.

By adopting such a configuration, in the water injection parts adjacent to each other in the circumferential direction, the liquid droplets of the water injected from the first nozzle of one water injection part and the liquid droplets of the water injected from the second nozzle of the other water injection part are prevented from interfering with each other. Accordingly, the liquid droplets are prevented from coalescing and increasing in size. Therefore, the liquid droplets are likely to evaporate.

According to a seventh aspect of the present invention, the combustor according to any one of the first to sixth aspects may include an annular flow channel part and a water supply hole. The annular flow channel part is provided on the outer peripheral surface of the outer cylinder. The annular flow channel part is continuous in the circumferential direction and is supplied with water from the outside. The water supply hole penetrates the outer cylinder in a radial direction. The water supply hole supplies water from the annular flow channel part to each of the plurality of water injection parts.

By adopting such a configuration, water is prevented from being exposed to heat in the outer cylinder of the combustor until the water supplied from the outside reaches the annular flow channel part. Accordingly, piping lines or the like of a system that supplies water are prevented from being affected by thermal stress.

According to an eighth aspect of the present invention, a gas turbine includes the combustor according to any one of the first to seventh aspects.

By doing so, the marketability of the gas turbine can be improved.

Advantageous Effects of Invention

According to the combustor, it is possible to further reduce NOx and soot.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a cross-sectional view showing an internal configuration of a combustor according to an embodiment of the present invention.

FIG. **2** is an enlarged cross-sectional view showing main parts of the combustor.

FIG. **3** is a cross-sectional view taken along line A-A of FIG. **2**.

FIG. **4** is a view of a water injection part of the combustor as viewed from a radially inner side of an outer cylinder.

FIG. **5** is an enlarged cross-sectional view showing main parts of a combustor according to a second embodiment of the combustor.

FIG. **6** is a view of a water injection part of the second embodiment of the combustor as viewed from the radially inner side of the outer cylinder.

FIG. **7** is a view of a water injection part of a third embodiment of the combustor as viewed from the radially inner side of the outer cylinder.

FIG. **8** is an enlarged cross-sectional view showing main parts of a combustor according to a fourth embodiment of the combustor.

FIG. **9** is a view of a water injection part of the fourth embodiment of the combustor as viewed from the radially inner side of the outer cylinder.

FIG. **10** is an enlarged cross-sectional view showing main parts of a combustor according to a fifth embodiment of the combustor.

DESCRIPTION OF EMBODIMENTS

Hereinafter, combustor and gas turbines according to embodiments of the present invention will be described with reference to the drawings.

First Embodiment

FIG. **1** is a cross-sectional view showing an internal configuration of a combustor of this embodiment.

As shown in FIG. **1**, a combustor **10** of this embodiment is provided in a compartment **2** of a gas turbine **1**. The combustor **10** is of a dual type capable of both gas burning and oil burning. Compressed air generated by a compressor of the gas turbine **1** (not shown) is introduced into the combustor **10**. The combustor **10** injects fuel into the introduced compressed air to generate high-temperature and high-pressure combustion gas.

The combustor **10** mainly includes an outer cylinder **11**, a combustor liner **12**, a transition piece **13**, a back wall **14**, a pilot nozzle **21**, a main nozzle (fuel nozzle) **22**, an air flow channel part R, and a water injection part **30**.

The outer cylinder **11** is supported by the compartment **2** of the gas turbine **1**. The outer cylinder **11** is formed in a tubular shape extending in an axial direction Da in which a central axis O extends.

The combustor liner **12** is provided on a radially inner side centered on the central axis O with respect to the outer cylinder **11**. The combustor liner **12** has a tubular shape extending in the axial direction Da. An end portion **12***a* of the combustor liner **12** on a first side Da**1** in the axial direction Da is disposed on the radially inner side, centered on the central axis O of an end portion **11***a* of the outer cylinder **11** on the first side Da**1** in the axial direction Da. An end portion **12***b* of the combustor liner **12** on a second side Da**2** in the axial direction Da is disposed closer to a second side Da**2** than an end portion **11***b* of the outer cylinder **11** on the second side Da**2** in the axial direction Da. In addition, as the combustor liner **12** in this embodiment, a case where the combustor liner **12** has a cylindrical portion **51** (described below) at the end portion **12***a* on the first side Da**1** in the axial direction Da is an exemplary example.

The transition piece **13** is provided on a radially outer side of the end portion **12***b* of the combustor liner **12** on the second side Da**2**. The transition piece **13** has a tubular shape extending in the axial direction Da.

The back wall **14** closes the end portion **11***a* of the outer cylinder **11** on the first side Da**1** in the axial direction Da. The back wall **14** has a guide surface **15** continuous in a circumferential direction Dc around the central axis O. The guide surface **15** is a curved surface that is concave to the first side Da**1** in the axial direction Da as viewed from a direction orthogonal to the central axis O. The guide surface **15** is disposed at a distance from the end portion **12***a* of the combustor liner **12** on the first side Da**1**.

The pilot nozzle **21** is provided along the central axis O of the combustor liner **12**. The pilot nozzle **21** injects the fuel supplied from the outside from a tip portion **21***a*. A flame is generated by igniting the fuel injected from the pilot nozzle **21**.

The pilot nozzle **21** includes a pilot cone **24**. The pilot cone **24** is formed in a tubular shape that surrounds the tip portion **21***a* of the pilot nozzle **21** from an outer peripheral side. The pilot cone **24** has a tapered cone portion **24***c*. The inner diameter of the tapered cone portion **24***c* gradually increases in a flame generation direction from the vicinity of the tip portion **21***a* of the pilot nozzle **21**. The tapered cone portion **24***c* regulates the diffusion range and direction of the flame and enhances the flame retention performance.

A pilot swirler **28** is provided between an outer peripheral surface of the pilot nozzle **21** and an inner peripheral surface of the pilot cone **24**. The pilot swirler **28** straightens the air supplied into the pilot cone **24**.

A plurality of main nozzles **22** are provided in the combustor liner **12**. The plurality of main nozzles **22** are disposed at intervals in the circumferential direction Dc on the radially outer side of the pilot nozzle **21**. Each main nozzle **22** extends in the axial direction Da of the combustor liner **12**.

A main burner **25** is provided on an outer peripheral side of the tip portion **22***a* of the main nozzle **22**. The main burner **25** has a tubular shape, and a side **25***a* closer to the pilot cone **24** on the center side of the combustor liner **12** is formed so as to gradually incline toward the outer peripheral side in the flame generation direction.

A main swirler **29** is provided between an outer peripheral surface of the tip portion **22***a* of the main nozzle **22** and an inner peripheral surface of the main burner **25**. The main swirler **29** straightens the air supplied into the main burner **25**.

FIG. **2** is an enlarged cross-sectional view showing main parts of the combustor.

As shown in FIGS. **1** and **2**, the air flow channel part R includes an introduction flow channel portion R**1**, a reversing flow channel portion R**2**, and an internal flow channel portion R**3**.

The introduction flow channel portion R**1** is formed between an inner peripheral surface **11***f* of the outer cylinder **11** and an outer peripheral surface **12***g* of the combustor liner **12**. Air is introduced into the introduction flow channel portion R**1** from an opening **16** formed in a gap between the end portion **11***b* of the outer cylinder **11** on the second side Da**2** in the axial direction Da and the outer peripheral surface **12***g* of the combustor liner **12**. A punch metal **27** is provided in the opening **16**. The punch metal **27** is a perforated plate in which a large number of holes are formed. The punch metal **27** straightens the air flowing in from the compressor (not shown) of the gas turbine **1**. The air introduced into the introduction flow channel portion R**1** flows toward the first side Da**1** in the axial direction Da in the introduction flow channel portion R**1**.

The reversing flow channel portion R**2** reverses the flow direction of the air introduced into the introduction flow channel portion R**1** to the second side Da**2** in the axial direction Da. A cylindrical portion **51** and a guide vane **52** are provided in the reversing flow channel portion R**2**. The cylindrical portion **51** forms the end portion **12***a* of the combustor liner **12** on the first side Da**1** described above. The cylindrical portion **51** has a bell mouth structure that bulges radially outward. The guide vane **52** is provided between the main nozzles **22** adjacent to each other in the circumferential direction Dc. The guide vane **52** extends to be curved radially inward from the vicinity of the tip **51***a* of the first side Da**1** of the cylindrical portion **51** toward the second side Da**2** in the axial direction Da.

The reversing flow channel portion R**2** reverses the air introduced into the introduction flow channel portion R**1** by the guide surface **15** of the back wall **14** and the guide vane **52** so as to flow from the radially inner side to the second side Da**2** in the axial direction Da. The air of which the flow direction has been changed by the reversing flow channel portion R**2** is sent to the internal flow channel portion R**3** in the combustor liner **12**.

The internal flow channel portion R**3** is formed on the radially inner side of the combustor liner **12**. The air of which the flow direction is reversed by the reversing flow channel portion R**2** flows through the internal flow channel portion R**3** from the end portion **12***a* of the combustor liner **12** on the first side Da**1** in the axial direction Da toward the end portion **12***b* on the second side Da**2** in the axial direction Da.

FIG. **3** is a cross-sectional view taken along the line A-A of FIG. **2**.

As shown in FIGS. **2** and **3**, a plurality of the water injection parts **30** are provided at equal intervals in the circumferential direction Dc around the central axis O. Each water injection part **30** is disposed on the radially outer side of the end portion **12***a* of the combustor liner **12**. Each water injection part **30** is disposed on an upstream side of the reversing flow channel portion R**2** in the flow direction. The water injection part **30** injects water into the air flowing through the air flow channel part R. The water injection part **30** is provided on the inner peripheral surface **11***f* of the outer cylinder **11**. The water injection part **30** injects water from the inner peripheral surface **11***f* side of the outer cylinder **11** toward the introduction flow channel portion R**1** on the radially inner side inside the combustor **10**.

FIG. **4** is a view of a water injection part of the combustor as viewed from the radially inner side of the outer cylinder.

As shown in FIGS. **3** and **4**, each water injection part **30** includes a bracket **31**, a first nozzle **32**, and a second nozzle **33**.

The bracket **31** is fixed to the inner peripheral surface **11***f* of the outer cylinder **11**. The bracket **31** has a fixed surface **31***b*, a first inclined surface **31***s*, and a second inclined surface **31***t*.

The fixed surface **31***b* abuts against the inner peripheral surface **11***f* of the outer cylinder **11**. The bracket **31** is fixed to the inner peripheral surface **11***f* by appropriate fixing means such as welding or bolts in a state where the fixed surface **31***b* abuts against the inner peripheral surface **11***f*.

The first inclined surface **31***s* is inclined to the first side Dc**1** in the circumferential direction Dc with respect to the radial direction Dr facing the central axis O of the outer cylinder **11**. The second inclined surface **31***t* is inclined to the second side Dc**2** in the circumferential direction Dc with respect to the radial direction Dr facing the central axis O of the outer cylinder **11**. In other words, the first inclined surface **31***s* and the second inclined surface **31***t* are in contact with each other on the radially innermost side about the central axis O and is inclined so as to be separated from each other toward the radially outer side (in other words, as being closer to the inner peripheral surface **11***f*). Although the first inclined surface **31***s* and the second inclined surface **31***t* in this embodiment are symmetrically formed in the circumferential direction, respectively, and are formed in a planar shape having a constant inclination, the present invention is not limited to this configuration.

The first nozzle **32** is provided on the first inclined surface **31***s*. The first nozzle **32** is formed with a nozzle hole **32***h* for injecting water. The second nozzle **33** is provided on the second inclined surface **31***t*. The second nozzle **33** is formed with a nozzle hole **33***h* for injecting water.

The hole diameter of the nozzle hole **32***h* of the first nozzle **32** provided as an exemplary example in the first embodiment and the hole diameter of the nozzle hole **33***h* of the second nozzle **33** are the same. The range of the effective area of the nozzle holes **32***h* and **33***h* can be, for example, 0.01 mm^2 to 2.0 mm^2. Moreover, the range of the effective area of the nozzle holes **32***h* and **33***h* may be, for example, 2.0 mm^2 to 20.0 mm^2. In addition, effective area=Mass flow rate/(2×Differential pressure×Water density)$^{0.5}$ is established.

Water is supplied from an external water supply source (not shown) to such a plurality of water injection parts **30**. For that reason, as shown in FIG. **2**, a supply flow channel **35** for supplying water to each water injection part **30** is formed on the back wall **14**. The water injection part **30** includes a flow channel forming member **36** that connects the supply flow channel **35** and the bracket **31** to each other and supplies water to the bracket **31**. The flow channel forming member **36** extends in the axial direction Da and forms a water flow channel **36***r* between the flow channel forming member **36** and the inner peripheral surface **11***f* of the outer cylinder **11**. Water is supplied from the supply flow channel **35** through the flow channel **36***r* formed by the flow channel forming member **36** to the bracket **31**.

In such a water injection part **30**, water is supplied from the external water supply source (not shown) through the supply flow channel **35** and the flow channel **36***r* to the bracket **31**. The water supplied to the bracket **31** is distributed to the first nozzle **32** and the second nozzle **33** in the bracket **31**. In the first nozzle **32** and the second nozzle **33**, the water distributed in the bracket **31** is injected from the nozzle holes **32***h* and **33***h*. As shown in FIG. **4**, the first nozzle **32** provided on the first inclined surface **31***s* of the bracket **31** injects water to the first side Dc**1** in the circumferential direction Dc. Additionally, the second nozzle **33** provided on the second inclined surface **31***t* of the bracket **31** injects water to the second side Dc**2** in the circumferential direction Dc.

In this way, the water injection part **30** injects water from the inner peripheral surface **11***f* of the outer cylinder **11**. The liquid droplets injected from the water injection part **30** are injected into the air flowing through the air flow channel part R on the immediate upstream side of the reversing flow channel portion R**2**. The liquid droplets of the injected water are sent into the combustor liner **12** together with the air. The liquid droplets evaporate due to the heat of a flame generated by the main burner **25**.

Therefore, according to the combustor **10** of the first embodiment described above, the water injection part **30** injects water from the inner peripheral surface **11***f* of the outer cylinder **11**. Accordingly, liquid droplets are atomized and easily evaporated before reaching a portion where the fuel is injected from the main burner **25**. Additionally, water is injected from the inner peripheral surface **11***f* of the outer cylinder **11** toward the inner side of the outer cylinder **11** in the radial direction Dr. Accordingly, even if a centrifugal force acts on the reversing flow channel portion R**2**, the liquid droplets of water are less likely to be biased to the outer side in the radial direction Dr. For that reason, it is possible to suppress a decrease in the amount of liquid droplets reaching the portion where the fuel is injected from the main nozzle **22**. Moreover, the first nozzle **32** injects water to the first side Dc**1** in the circumferential direction Dc. The second nozzle **33** injects water to the second side Dc**2** in the circumferential direction Dc. Accordingly, the distribution of the liquid droplets in the air flow channel part R becomes non-uniform, and the dispersibility of the liquid droplets is enhanced. As a result, it is possible to reduce the flame temperature in the combustor **10** and further reduce NOx, soot, and the like. Additionally, the liquid droplets evaporate to generate steam, which increases the volume of air containing the steam and improves the output of the gas turbine **1**.

The water injection part **30** of the first embodiment includes the bracket **31** fixed to the inner peripheral surface **11***f* of the outer cylinder **11**. The first nozzle **32** and the second nozzle **33** are provided on the bracket **31**. By adopting such a configuration, the water injection part **30** can be easily installed by simply attaching the bracket **31** provided with the first nozzle **32** and the second nozzle **33** to the inner peripheral surface **11***f* of the outer cylinder **11**.

The bracket **31** of the first embodiment has the first inclined surface **31***s* and the second inclined surface **31***t*. Accordingly, the first nozzle **32** provided on the first inclined surface **31***s* of the bracket **31** injects water to the first side Dc**1** in the circumferential direction Dc. Additionally, the second nozzle **33** provided on the second inclined surface **31***t* of the bracket **31** injects water to the second side Dc**2** in the circumferential direction Dc. By using such a bracket **31**, the first nozzle **32** and the second nozzle **33** can be easily installed in a state of being inclined in a predetermined direction.

Second Embodiment

Next, a second embodiment of the combustor according to the present invention will be described. In the second embodiment described below, only the configurations of a first nozzle **32**B and a second nozzle **33**B are different from those of the first embodiment. Thus, the same portions as those in the first embodiment will be described with the same reference numerals, and duplicate descriptions thereof will be omitted.

FIG. **5** is an enlarged cross-sectional view showing main parts of the combustor according to the second embodiment of the combustor. FIG. **6** is a view of a water injection part of the second embodiment of the combustor as viewed from the radially inner side of the outer cylinder.

As shown in FIG. **1**, a combustor **10**B in this embodiment mainly includes the outer cylinder **11**, the combustor liner **12**, the transition piece **13**, the back wall **14**, the pilot nozzle **21**, the main nozzle **22**, the air flow channel part R, and a water injection part **30**B.

As shown in FIGS. **5** and **6**, each water injection part **30**B includes the bracket **31**, a first nozzle **32**B, and a second nozzle **33**B.

The first nozzle **32**B is provided on the first inclined surface **31***s*. The first nozzle **32**B is formed with the nozzle hole **32***h* for injecting water.

The second nozzle **33**B is provided on the second inclined surface **31***t*. The second nozzle **33**B is formed with the nozzle hole **33***h* for injecting water.

The first nozzle **32**B and the second nozzle **33**B of the water injection parts **30** (refer to FIG. **3**) adjacent to each other in the circumferential direction Dc are provided at different positions in the axial direction Da. In other words, in the water injection parts **30** adjacent to each other in the circumferential direction Dc, the first nozzle **32**B of one water injection part **30**B and the second nozzle **33**B of the other water injection part **30**B are provided at different positions in the axial direction Da.

As shown in FIGS. **4** and **5**, in the second embodiment, the first nozzle **32**B of the one water injection part **30**B is provided at a position of the first inclined surface **31***s* of the bracket **31** on the first side Da**1** side in the axial direction Da. Moreover, the second nozzle **33**B of the other water injection part **30**B is provided at a position of the inclined surface **31***t* of the bracket **31** on the second side Da**2** side in the axial direction Da. Additionally, in each water injection part **30**B, the first nozzle **32**B provided on the first inclined surface **31***s* of the bracket **31** and the second nozzle **33**B provided on the second inclined surface **31***t* are at mutually different positions in the axial direction Da. Accordingly, as shown in FIG. **4**, the liquid droplets of the water injected from the first nozzle **32**B and the liquid droplets of the water injected from the second nozzle **33**B are at different positions in the axial direction Da.

Therefore, according to the combustor **10**B of the second embodiment described above, in the water injection parts **30**B adjacent to each other in the circumferential direction Dc, the liquid droplets of the water injected from the first nozzle **32**B of one water injection part **30**B and the liquid droplets of the water injected from the second nozzle **33**B of the other water injection part **30**B are prevented from interfering with each other. Accordingly, it is possible to prevent the liquid droplets from coalescing into one droplet and increasing in size. As a result, the liquid droplets can be easily evaporated.

In the second embodiment, similar to the first embodiment, it is possible to reduce the flame temperature in the combustor **10**B and further reduce NOx, soot, and the like. Additionally, the liquid droplets evaporate to generate steam, which increases the volume of air containing the steam and improves the output of the gas turbine **1**.

Third Embodiment

Next, a third embodiment of the combustor according to the present invention will be described. In the third embodiment described below, only the configurations of a first nozzle **32**C and a second nozzle **33**C are different from those of the first embodiment. Thus, the same portions as those in the first embodiment will be described with the same reference numerals, and duplicate descriptions thereof will be omitted.

FIG. **7** is a view of a water injection part of the third embodiment of the combustor as viewed from the radially inner side of the outer cylinder.

As shown in FIG. **1**, a combustor **10**C in this embodiment mainly includes the outer cylinder **11**, the combustor liner **12**, the transition piece **13**, the back wall **14**, the pilot nozzle **21**, the main nozzle **22**, the air flow channel part R, and a water injection part **30**C.

As shown in FIG. **7**, each water injection part **30**C includes the bracket **31**, the first nozzle **32**C, and the second nozzle **33**C.

The first nozzle **32**C is provided on the first inclined surface **31***s*. The first nozzle **32**C is formed with a nozzle hole **32***j* for injecting water.

The second nozzle **33**C is provided on the second inclined surface **31***t*. The second nozzle **33**C is formed with a nozzle hole **33***j* for injecting water.

In the third embodiment, the diameters of the nozzle holes **32***j* and **33***j* for injecting water are different from each other between the first nozzle **32**C and the second nozzle **33**C adjacent to each other in the circumferential direction Dc. That is, in each water injection part **30**C, a diameter d**1** of the nozzle hole **32***j* of the first nozzle **32**C provided on the first inclined surface **31***s* of the bracket **31** and a diameter d**2** of the nozzle hole **33***j* of the second nozzle **33**C provided on the second inclined surface **31***t* of the bracket **31** are different from each other. Accordingly, in the water injection parts **30**C adjacent to each other in the circumferential direction Dc, the diameter d**1** of the nozzle hole **32***j* of the first nozzle **32**C provided in one water injection part **30**C and the diameter d**2** of the nozzle hole **33***j* of the second nozzle **33**C provided in the other water injection part **30**C are different from each other.

In this embodiment, the range of the effective area of the nozzle hole **32***j* can be, for example, 0.01 mm^2 to 2.0 mm^2. Moreover, the range of the effective area of the nozzle hole **32***j* may be, for example, 2.0 mm^2 to 20.0 mm^2. In contrast, the range of the effective area of the nozzle hole **33***j* can be, for example, 0.01 mm^2 to 2.0 mm^2. Moreover, The range of the effective area of the nozzle hole **33***j* can be, for example, 2.0 mm^2 to 20.0 mm^2.

According to the combustor **10**C of the third embodiment described above, the diameters d**1** and d**2** of the nozzle holes **32***j* and **33***j* are different from each other between the first nozzle **32**C and the second nozzle **33**C. Accordingly, the momentum (flow velocity) of water (liquid droplets) to be injected are different between the first nozzle **32**C and the second nozzle **33**C. For that reason, distances at which the liquid droplets injected from the first nozzle **32**C and the second nozzle **33**C, respectively, reach in injection directions are different from each other. Additionally, the grain size of the liquid droplets is also different between the first nozzle **32**C and the second nozzle **33**C. Accordingly, the distribution of the liquid droplets in the air flow channel part R becomes non-uniform, and the dispersibility of the liquid droplets is enhanced. As a result, it is possible to reduce the flame temperature in the combustor **10**C and further reduce NOx, soot, and the like. Additionally, the liquid droplets evaporate to generate steam, which increases the volume of air containing the steam and improves the output of the gas turbine **1**.

Fourth Embodiment

Next, a fourth embodiment of the combustor according to the present invention will be described. In the fourth embodiment described below, only the configurations of a first nozzle **32**D and a second nozzle **33**D are different from those of the first embodiment. Thus, the same portions as those in the first embodiment will be described with the same reference numerals, and duplicate descriptions thereof will be omitted.

FIG. **8** is an enlarged cross-sectional view showing main parts of the combustor according to the fourth embodiment of the combustor. FIG. **9** is a view of a water injection part of the fourth embodiment of the combustor as viewed from the radially inner side of the outer cylinder.

As shown in FIG. **1**, a combustor **10**D in this embodiment mainly includes the outer cylinder **11**, the combustor liner **12**, the transition piece **13**, the back wall **14**, the pilot nozzle **21**, the main nozzle **22**, the air flow channel part R, and a water injection part **30**D.

As shown in FIGS. **8** and **9**, each water injection part **30**D includes the bracket **31**, the first nozzle **32**D, and the second nozzle **33**D.

The first nozzle **32**D is provided on the first inclined surface **31***s*. The first nozzle **32**D is formed with a nozzle hole **32***k* for injecting water.

The second nozzle **33**D is provided on the second inclined surface **31***t*. The second nozzle **33**D is formed with a nozzle hole **33***k* for injecting water.

The first nozzle **32**D and the second nozzle **33**D, which are adjacent to each other in the circumferential direction Dc, have mutually different water injection directions in the axial direction Da. In each water injection part **30**D, the first nozzle **32**D provided on the first inclined surface **31***s* of the bracket **31** and the second nozzle **33**D provided on the second inclined surface **31***t* of the bracket **31** have water injection directions from the nozzle holes **32***k* and **33***k* that are different from each other in the axial direction Da. In the third embodiment, the nozzle hole **32***k* of the first nozzle **32**D injects water in a direction inclined to the first side Da**1** with respect to the direction orthogonal to the axial direction Da. The nozzle hole **33***k* of the second nozzle **33**D injects water in a direction inclined toward the second side Da**2** with respect to the direction orthogonal to the axial direction Da. Accordingly, as shown in FIG. **3**, in the water injection parts **30**D adjacent to each other in the circumferential direction Dc, the first nozzle **32**D provided in one water injection part **30**D and the second nozzle **33**D provided in the other water injection part **30**D have water injection directions from the nozzle holes **32***k* and **33***k* that are different from each other in the axial direction Da.

Therefore, according to the combustor **10**D of the fourth embodiment described above, between the water injection parts **30**D adjacent to each other in the circumferential direction Dc, the liquid droplets of the water injected from the first nozzle **32**D of one water injection part **30**D and the liquid droplets of the water injected from the second nozzle **33**D of the other water injection part **30**D are prevented from interfering with each other. Accordingly, the liquid droplets are prevented from coalescing and increasing in size. Therefore, the liquid droplets are likely to evaporate. Accordingly, it is possible to reduce the flame temperature in the combustor **10**D and further reduce NOx, soot, and the like. Additionally, the liquid droplets evaporate to generate steam, which increases the volume of air containing the steam and improves the output of the gas turbine **1**.

In addition, in the fourth embodiment, the first nozzle **32**D injects water in the direction inclined toward the first side Da**1** in the axial direction Da, and the second nozzle **33**D injects water in the direction inclined toward the second side Da**2** in the axial direction Da. However, the present invention is not limited to this. Both the first nozzle **32**D and the second nozzle **33**D may have, for example, mutually different inclination angles while injecting water in the direction inclined to the first side Da**1** in the axial direction Da Additionally, both the first nozzle **32**D and the second nozzle **33**D may have, for example, mutually different inclination angles while injecting water in the direction inclined to the second side Da**2** in the axial direction Da.

Moreover, either one of the first nozzle **32**D and the second nozzle **33**D may inject water in the direction orthogonal to the axial direction Da without being inclined to the first side Da**1** or the second side Da**2** in the axial direction Da. In this case, the other of the first nozzle **32**D and the second nozzle **33**D injects water in the direction inclined toward the first side Da**1** or the second side Da**2** in the axial direction Da.

Fifth Embodiment

Next, a fifth embodiment of the combustor according to the present invention will be described. In the fifth embodiment described below, only the configurations of a first nozzle **32** and a second nozzle **33** are different from those of the first embodiment. Thus, the same portions as those in the first embodiment will be described with the same reference numerals, and duplicate descriptions thereof will be omitted.

FIG. **10** is an enlarged cross-sectional view showing main parts of the combustor according to the fifth embodiment of the combustor.

As shown in FIG. **1**, a combustor **10**E in this embodiment mainly includes the outer cylinder **11**, the combustor liner **12**, the transition piece **13**, the back wall **14**, the pilot nozzle **21**, the main nozzle **22**, the air flow channel part R, and a water injection part **30**E.

A plurality of the water injection parts **30**E are provided at equal intervals in the circumferential direction around the central axis O. As shown in FIG. **10**, each water injection part **30**E includes the bracket **31**, the first nozzle **32**, and the second nozzle **33**.

Water is supplied from the external water supply source (not shown) to the plurality of water injection parts **30**E. For this reason, the combustor **10**E includes an annular flow channel part **40** and a water supply hole **41**.

The annular flow channel part **40** is provided on the outer side of the outer cylinder **11** in the radial direction Dr. The annular flow channel part **40** is provided on an outer peripheral surface **11***g* of the outer cylinder **11**. The annular flow channel part **40** is continuous in the circumferential direction Dc. Water is supplied from the outside via a water supply pipe **42** to the annular flow channel part **40**. The water supply pipe **42** is provided through a gap between an inner peripheral surface of the compartment **2** (refer to FIG. **1**) of the gas turbine **1** and an outer peripheral surface of the combustor **10**E.

The water supply hole **41** penetrates the outer cylinder **11** in the radial direction Dr. The water supply hole **41** is formed on a radially outer side of each of the plurality of water injection parts **30**E. The water supply hole **41** supplies water from the annular flow channel part **40** to each of the plurality of water injection parts **30**B.

In such a water injection part **30**E, water is supplied from the external water supply source (not shown) through the water supply pipe **42**, the annular flow channel part **40**, and each water supply hole **41** to the bracket **31**. The water supplied to the bracket **31** is distributed to the first nozzle **32** and the second nozzle **33**. In the first nozzle **32** and the second nozzle **33**, the water distributed in the bracket **31** is injected.

Therefore, according to the combustor **10**E of the fifth embodiment described above, the water supply pipe **42** and the annular flow channel part **40** are prevented from being exposed to heat inside the outer cylinder **11** of the combustor **10**E until the water supplied from the outside reaches the annular flow channel part **40**. Accordingly, the water supply pipe **42** and the annular flow channel part **40** are prevented from being affected by thermal stress.

Additionally, similar to the first to fourth embodiments, the first nozzle **32** injects water to the first side Dc**1** in the circumferential direction Dc. The second nozzle **33**D injects water to the second side Dc**2** in the circumferential direction Dc. Accordingly, the distribution of the liquid droplets in the air flow channel part R becomes non-uniform, and the dispersibility of the liquid droplets is enhanced. Therefore, it is possible to further reduce NOx and soot. Additionally, the liquid droplets evaporate to generate steam, which increases the volume of air containing the steam and improves the output of the gas turbine **1**.

Other Modification Examples

In addition, the present invention is not limited to the above-described embodiments and includes making various changes to the above-described embodiments without departing from the spirit of the present invention. That is, the specific shape, configuration, and the like given in the embodiments are merely examples and can be appropriately changed. For example, the configurations shown in the first to fifth embodiments can be appropriately combined.

INDUSTRIAL APPLICABILITY

According to the combustor, it is possible to further reduce NOx and soot.

REFERENCE SIGNS LIST

1: Gas turbine
2: Compartment
10, **10**B, **10**C, **10**D, **10**E: Combustor
11: Outer cylinder
11*a*: End portion
11*b*: End portion
11*f*: Inner peripheral surface
11*g*: Outer peripheral surface
12: Combustor liner
12*a*: End portion
12*b*: End portion
12*g*: Outer peripheral surface
13: Transition piece
14: Back wall
15: Guide surface
16: Opening
21: Pilot nozzle
21*a*: Tip portion
22: Main nozzle (fuel nozzle)
22*a*: Tip portion
24: Pilot cone
24*c*: Tapered cone portion
25: Main burner

25*a*: Side closer to pilot cone
27: Punch metal
28: Pilot swirler
29: Main swirler
30, **30**B, **30**C, **30**D, **30**E: Water injection part
31: Bracket
31*b*: Fixed surface
31*s*: First inclined surface
31*t*: Second inclined surface
32, **32**B, **32**C, **32**D: First nozzle
32*h*, **32***j*, **32***k*: Nozzle hole
33, **33**B, **33**C, **33**D: Second nozzle
33*h*, **33***j*, **33***k*: Nozzle hole
35: Supply flow channel
36: Flow channel forming member
36*r*: Flow channel
40: Annular flow channel part
41: Water supply hole
42: Water supply pipe
51: Cylindrical portion
51*a*: Tip
52: Guide vane
O: Central axis
R: Air flow channel part
R**1** Introduction flow channel portion
R**2**: Reversing flow channel portion
R**3**: Internal flow channel portion

The invention claimed is:

1. A combustor comprising:
a tubular outer cylinder extending in an axial direction;
a tubular-shaped combustor liner extending in the axial direction and that is provided on a radially inner side of the tubular outer cylinder;
a plurality of fuel nozzles that are provided inside the tubular-shaped combustor liner and configured to inject fuel;
an air flow channel part that is configured to send air, which is introduced from an outside to between an inner peripheral surface of the tubular outer cylinder and an outer peripheral surface of the tubular-shaped combustor liner, into the tubular-shaped combustor liner; and
a plurality of water injection parts that are provided on the inner peripheral surface of the tubular outer cylinder at intervals in a circumferential direction about an axis and is configured to inject water toward the radially inner side of the tubular outer cylinder,
wherein each of the plurality of water injection parts includes:
a first nozzle that is configured to inject water to a first side in the circumferential direction; and
a second nozzle that is configured to inject water to a second side in the circumferential direction.

2. The combustor according to claim **1**,
wherein each of the plurality of water injection parts includes a bracket fixed to the inner peripheral surface of the tubular outer cylinder, and
the first nozzle and the second nozzle are provided on the bracket.

3. The combustor according to claim **2**,
wherein the bracket has
a first inclined surface that is inclined to the first side in the circumferential direction and is provided with the first nozzle, and
a second inclined surface that is inclined to the second side in the circumferential direction and is provided with the second nozzle.

4. The combustor according to claim **1**,

wherein in water injection parts of the plurality of water injection parts adjacent to each other in the circumferential direction, the first nozzle of one water injection part and the second nozzle of the other water injection part are provided at different positions in the axial direction.

5. The combustor according to claim **1**,

wherein in water injection parts of the plurality of water injection parts adjacent to each other in the circumferential direction, diameters of nozzle holes for injecting water are different from each other between the first nozzle and the second nozzle.

6. The combustor according to claim **1**,

wherein in water injection parts of the plurality of water injection parts adjacent to each other in the circumferential direction, the first nozzle and the second nozzle have water injection directions that are different from each other in the axial direction.

7. The combustor according to claim **1**, further comprising:

an annular flow channel part that is provided on an outer peripheral surface of the tubular outer cylinder to be continuous in the circumferential direction and to which water is supplied from the outside; and

a water supply hole that penetrates the tubular outer cylinder in a radial direction and is configured to supply water from the annular flow channel part to each of the plurality of water injection parts.

8. A gas turbine comprising:

the combustor according to claim **1**.

* * * * *